Performance trends in individual medley events during FINA World Master Championships from 1986 to 2014

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Abstract: BACKGROUND: Performance trends during the last decades in elite individual medley swimmers are known, but not for age groups swimmers. Therefore, the aim of the present study was to examine participation and performance trends in age groups swimmers competing in FINA World Masters Championships (1986-2014) in individual 200m and 400m medley. METHODS: We included all swimmers (women, n=6,424; men, n=7,588) for each distance and age groups (25-29 to 95-99 years) in the analysis to avoid a selection bias by limiting to a fixed sample (e.g. the ten fastest). Changes in participation and changes in sex difference across editions were analyzed using linear regression models. Changes in performance across editions were analyzed using a mixed-effects regression model with finisher as random variable to consider finishers who completed several races. Sex, distance and calendar year were included as fixed variables. We also considered interaction effects between sex and distance. The men-to-women ratio was compared using a paired t-test. RESULTS: In 200m, the participation of women increased from 35-39 to 75-79 years and of men from 35-39 to 85-89 years ($p<0.05$). In 400m, the participation of women increased from 50-54 to 75-79 years and of men from 60-64 to 85-89 years ($p<0.05$). From 25-29 to 90-94 years, women and men improved performance in both editions ($p<0.05$). Men were faster than women from 25-29 to 80-84 years ($p<0.05$), but not in 85-90 and 90-94 years. Sex and distance showed a significant interaction from 25-29 to 85-89 years ($p<0.05$), but not in 90-94 years. Women reduced the gap to men in 40-44 and 45-49 years in 200m, and 40-44 years in 400m ($p<0.05$). CONCLUSIONS: In summary, the participation increased in older age groups (>35 years), women and men from 25-29 to 90-94 years improved, and men were faster than women from 25-29 to 80-84 years, but not from 85-89 to 90-94 years. These data suggest that master swimmers will continue to increase participation and improve performance in individual medley. The findings of the present study might help coaches and fitness trainers of medley swimmers to tailor their training programs considering the age of their swimmers.

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ORIGINAL ARTICLE

Performance trends in individual medley events during FINA World Master Championships from 1986 to 2014

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ABSTRACT

BACKGROUND: Performance trends during the last decades in elite individual medley swimmers are known, but not for age groups swimmers. Therefore, the aim of the present study was to examine participation and performance trends in age groups swimmers competing in FINA World Masters Championships (1986-2014) in individual 200-m and 400-m medley.

METHODS: We included all swimmers (6424 women, 7588 men) for each distance and age groups (25-29 to 95-99 years) in the analysis to avoid a selection bias by limiting to a fixed sample (*e.g.* the ten fastest). Changes in participation and changes in sex difference across editions were analyzed using linear regression models. Changes in performance across editions were analyzed using a mixed-effects regression model with finisher as random variable to consider finishers who completed several races. Sex, distance and calendar year were included as fixed variables. We also considered interaction effects between sex and distance. The men-to-women ratio was compared using a paired *t*-test.

RESULTS: In 200 m, the participation of women increased from 35-39 to 75-79 years and of men from 35-39 to 85-89 years ($P<0.05$). In 400 m, the participation of women increased from 50-54 to 75-79 years and of men from 60-64 to 85-89 years ($P<0.05$). From 25-29 to 90-94 years, women and men improved performance in both editions ($P<0.05$). Men were faster than women from 25-29 to 80-84 years ($P<0.05$), but not in 85-90 and 90-94 years. Sex and distance showed a significant interaction from 25-29 to 85-89 years ($P<0.05$), but not in 90-94 years. Women reduced the gap to men in 40-44 and 45-49 years in 200 m, and 40-44 years in 400 m ($P<0.05$).

CONCLUSIONS: In summary, the participation increased in older age groups (>35 years), women and men from 25-29 to 90-94 years improved, and men were faster than women from 25-29 to 80-84 years, but not from 85-89 to 90-94 years. These data suggest that master swimmers will continue to increase participation and improve performance in individual medley. The findings of the present study might help coaches and fitness trainers of medley swimmers to tailor their training programs considering the age of their swimmers.

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Key words: Athletes - Swimming - Athletic performance - Sex characteristics - Aging.

Swimming can be performed in the four major strokes such as freestyle, backstroke, breaststroke and butterfly. The combination of the four strokes in one single race is called individual medley.[1] Each stroke has an equal part of the overall distance, *i.e.* a quarter of the overall distance is swum in each stroke. The strokes are swum in the order butterfly, backstroke, breaststroke and freestyle.[1] Usually, individual medley is held over 200 m and 400 m. The speed in individual medley is determined by kinematic parameters and technical skills.[2] The performance in the individual medley in both 200-m and 400-m events is influenced by the course length of the swimming pool with faster times being observed in the 25-m than in the 50-m course length.[3]

Improvements in swimming performance in the four major strokes have been well documented for elite swimmers competing at world class level (*e.g.* World Championships, Olympic Games).[4-6] For elite individual medley swimmers, the changes in performance

across years,[7] the age of the best performance [4, 8, 9] and the pacing strategy [10] have already been investigated.

The FINA holds apart from World Championships for elite swimmers since 1986 biannually the World Masters Championships for all disciplines and distances in pool and open-water swimming.[1] In master swimmers, it is known that swimming performance decreases with increasing age,[11, 12] but few data exist for changes in performance across years.[12] Mainly freestyle swimming has been investigated in age group swimmers. However, little is known for age group freestyle swimmers for distances from 100m to 800m or longer.[13] Akkari *et al.*[13] recently investigated changes in swimming performance in master swimmers competing in 100-m freestyle between 1975 and 2013.

However, trends in participation, performance and sex difference in performance of age group individual medley swimmers, are not known. Such knowledge would help coaches and trainers working with swimmers who compete in medley developing sex- and age-tailored training programs. Therefore, the aim of the present study was to investigate trends in changes of participation and performance in master swimmers competing in the FINA World Masters Championships held between 1986 and 2014 in 200m and 400m individual medley. We hypothesized that participation would increase and performance would improve in these age group swimmers as it has been shown for age group competing in other sports disciplines such as marathon [14-16] and ultra-marathon running.[17]

Materials and method

This study was approved by the Institutional Review Board of St. Gallen, Switzerland, with waiver of the requirement for informed consent given that the study involved the analysis of publicly available data.

All data were obtained from the official and free accessible FINA website.[1] FINA defines master swimmers as those equal or older than 25 years and records all competitors in 5-years age groups from 25-29 years to 105-109 years. All swimmers (6424 women, 7588 men) competing in all age groups in the FINA World Masters Championships in 200-m and 400-m individual medley between 1986 and 2014 (Table I) were analyzed for trends in participation, performance and sex difference in performance. Figure 1 summarizes the number of overall, women and men finishers for both 200-m and 400-m individual medley for each edition. For all ranked competitors, mean race time was calculated for all age groups for each year. The men-to-women ratio was calculated by dividing the number of men competitors by the number of women competitors for age groups and editions. Sex difference was calculated using the formula 100× [(race time in women) – (race time in men) / (race time in men)].

TABLE I.—*FINA World Master Championships from 1986 to 2014.*

Year	City
1986	Tokyo
1988	Brisbane
1990	Rio de Janeiro
1992	Indianapolis
1994	Montreal
1996	Sheffield
1998	Casablanca
2000	Munich
2002	Christchurch
2004	Riccione
2006	San Francisco
2008	Perth
2010	Goteborg
2012	Riccione
2014	Montreal

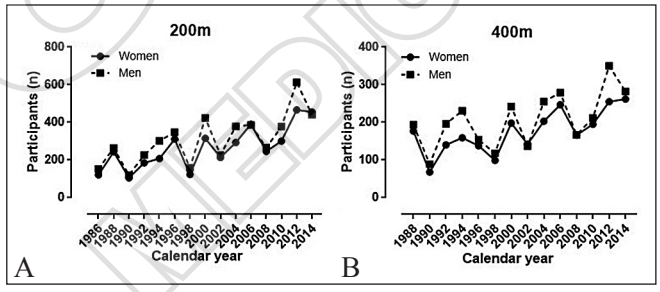

Figure 1.—Overall and by sex participation for 200-m (A) and 400-m medley (B) in FINA World Master Championships by calendar year.

Statistical analysis

To avoid a selection bias by limiting to a fixed sample (*e.g.* the ten fastest), we included all swimmers for each distance and age groups in the analysis. Changes in participation and changes in sex difference across editions were analyzed using linear regression models. Changes in performance across editions were analyzed using a mixed-effects regression model with participant identi-

fication (*i.e.* name of the swimmer) as random variable to consider swimmers who completed several races in several editions. Sex, distance and calendar year were included as fixed variables and race time was the dependent variable. We also considered interaction effects between sex and distance. A two-way analysis of variance examined the effect of sex and calendar year on race time for each race distance. The magnitude of these effects was examined using eta squared (η^2) evaluated as following: small ($0.010<\eta^2\leq0.059$), moderate ($0.059<\eta^2\leq0.138$) and large ($\eta^2>0.138$).[18] The men-to-women ratio was compared using a paired *t*-test. Statistical analyses were performed using IBM SPSS Statistics (v. 22, IBM SPSS, Chicago, IL, USA) and GraphPad Prism (v. 6.01, GraphPad Software, La Jolla, CA, USA). Significance was accepted at $P<0.05$ (two-sided for *t*-tests). Data in the text and tables are given as mean ± standard deviation.

Results

Participation trends

Between 1986 and 2014, a total of 14,012 swimmers were analyzed. In 200-m individual medley, 3975 women and 4682 men were classified between 1986 and 2014. In 400-m individual medley, 2449 women and 2906 men were recorded from 1988 to 2014. Figure 2 presents the trend in participation for women and men for 200 m and 400 m. In 200 m, participation increased in women in age groups 35-39 to 75-79 years and in men in age groups 35-39 to 85-89 years. In 400m, participation increased in women in age groups 50-54 to 75-79 years. In men, participation increased in age groups 60-64 to 85-89 years. Figure 3 shows the men-to-women ratio for 200-m and 400-m individual medley across editions. The men-to-women ratio remained unchanged in 200 m (r^2=0.05, P=0.44) and 400 m (r^2=0.04, P=0.49). In 200 m and 400 m, more men than women competed ($P<0.05$). Figure 4 presented the men-to-women ratio by age groups.

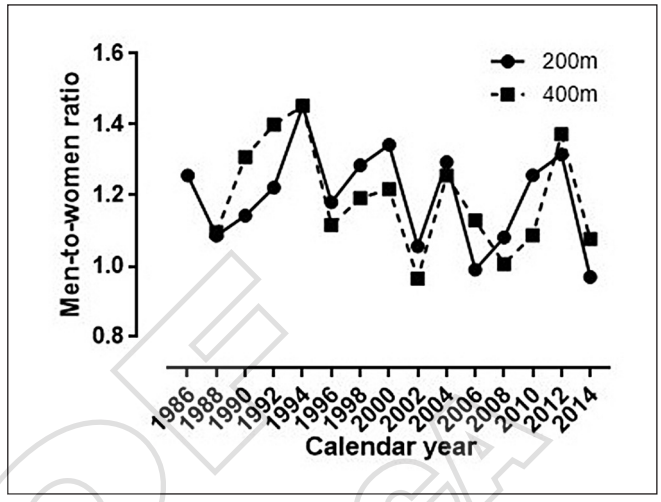

Figure 3.—The men-to-women ratio across editions for 200 m and 400 m.

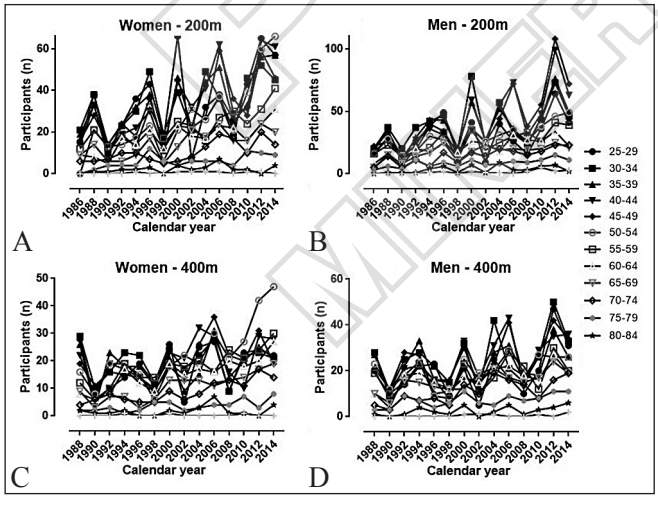

Figure 2.—A-D) Participation of women and men by age group for 200 m and 400 m.

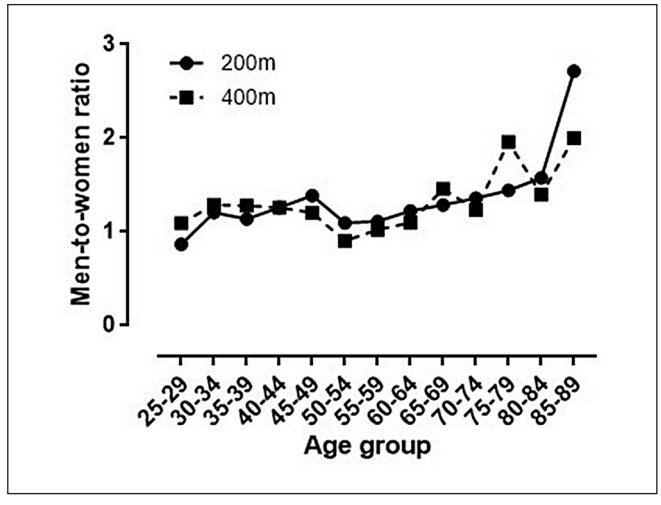

Figure 4.—Men-to-women ratio by age group for 200 m and 400 m.

TABLE II.—*Race times (min:sec) for women in age groups 25-29 to 90-94 years for 200 m and 400 m between 1986 and 2014.*

Distance	Age group	1986	1988	1990	1992	1994	1996	1998
200 m	25-29	3:08±0:26	2:56±0:16	3:03±0:18	2:50±0:14	3:00±0:20	2:55±0:17	2:48±0:08
	30-34	3:20±0:27	3:04±0:24	3:09±0:23	2:51±0:15	3:08±0:21	2:56±0:18	2:47±0:09
	35-39	3:38±0:26	3:26±0:25	3:05±0:20	2:58±0:42	3:08±0:23	3:04±0:18	2:53±0:12
	40-44	3:42±0:23	3:31±0:26	3:17±0:22	3:26±0:42	3:44±0:32	3:22±0:26	3:03±0:21
	45-49	3:52±0:29	3:41±0:27	3:35±0:31	3:27±0:27	3:33±0:29	3:26±0:27	3:11±0:18
	50-54		4:12±0:36	3:57±0:39	3:39±0:24	3:51±0:30	3:38±0:32	3:19±0:21
	55-59	4:02±0:23	4:22±0:46	4:37±0:41	4:03±0:30	3:58±0:28	3:54±0:28	3:38±0:18
	60-64	4:16±0:36	4:15±0:29	3:56±0:25	4:36±1:02	4:16±0:49	4:17±0:39	3:57±0:17
	65-69	5:14±0:60	4:32±0:21	4:59±1:21	4:07±0:29	4:19±0:40	4:43±0:38	4:31±0:32
	70-74	5:33±1:19	5:19±1:02	5:41±1:23	5:27±1:47	5:57±1:06	4:33±0:42	4:45±0:48
	75-79		7:24±2:25	5:21±0:49	5:33±0:57	6:19±2:26	5:50±1:11	5:51±1:00
	80-84		6:55	7:26	6:38±1:26	5:05±0:11	5:47±0:58	
	85-89					10:59		
	90-94							
400 m	25-29		6:02±0:32	5:50±0:11	5:52±0:19	6:04±0:30	6:01±0:31	5:55±0:21
	30-34		6:38±0:49	6:32±0:47	6:02±0:56	6:09±0:48	6:03±0:29	5:57±0:20
	35-39		6:51±0:42	7:08±0:50	6:30±0:41	6:27±0:42	6:28±0:38	6:13±0:24
	40-44		7:37±0:54	7:13±0:36	7:10±0:52	7:29±1:01	6:55±0:32	6:37±0:38
	45-49		7:33±0:44	7:38±0:59	7:07±0:58	7:38±1:04	7:00±0:32	6:49±0:48
	50-54		8:38±1:21	8:49±1:21	7:51±0:52	8:13±0:58	7:28±0:30	7:03±0:34
	55-59		8:42±1:02	9:48±1:14	8:03±0:46	8:33±1:12	7:57±0:39	7:41±0:44
	60-64		9:37±1:25	8:39±1:09	9:36±1:33	8:55±1:14	8:24±0:44	8:22±0:53
	65-69		9:52±1:17	9:13±1:05	9:07±1:13	9:13±1:04	9:26±0:35	9:42±0:37
	70-74		12:48±2:32	11:58±3:06	11:47±3:05	11:31±2:43	8:47±1:02	10:20±1:57
	75-79		15:36±4:27	12:45±0:20	12:12±1:35	20:29	10:42±1:20	12:44±2:54
	80-84		13:45±0:04	16:08	11:57	14:00±0:05		
	85-89					23:54		
	90-94							

TABLE III.—*Race times (min:sec) for men in age groups 25-29 to 90-94 years for 200 m and 400 m between 1986 and 2014.*

Distance	Age group	1986	1988	1990	1992	1994	1996	1998
200 m	25-29	2:37±0:11	2:40±0:26	2:32±0:05	2:30±0:11	2:39±0:18	2:31±0:12	2:33±0:08
	30-34	2:49±0:21	2:42±0:23	2:37±0:15	2:30±0:10	2:44±0:21	2:35±0:10	2:34±0:11
	35-39	2:54±0:20	2:54±0:22	2:44±0:13	2:40±0:19	2:50±0:18	2:45±0:20	2:28±0:08
	40-44	2:56±0:17	2:57±0:22	2:50±0:23	2:46±0:17	2:49±0:22	2:47±0:16	2:42±0:12
	45-49	3:20±0:38	3:02±0:24	2:52±0:14	2:55±0:28	3:06±0:26	2:56±0:21	2:47±0:13
	50-54	3:20±0:22	3:22±0:31	3:14±0:22	3:01±0:20	3:11±0:27	3:05±0:25	2:51±0:11
	55-59	3:42±0:45	3:27±0:26	3:34±0:35	3:16±0:21	3:14±0:19	3:22±0:31	3:00±0:17
	60-64	3:49±0:32	3:31±0:21	3:29±0:16	3:24±0:18	3:32±0:38	3:26±0:29	3:17±0:16
	65-69	4:20±0:55	3:43±0:19	4:35±0:41	3:40±0:24	3:54±0:44	3:33±0:22	3:38±0:20
	70-74	4:25±0:25	4:08±0:35	4:19±0:36	4:26±0:44	4:18±0:20	3:53±0:30	3:41±0:19
	75-79	6:03±1:37	4:37±0:57	4:25±0:19	4:25±0:38	4:30±0:44	4:18±0:36	4:41±0:55
	80-84		4:20	6:41	5:03	5:05±1:06	5:15±1:16	4:47
	85-89					5:07	5:22±0:07	
	90-94						7:08	
400 m	25-29		5:27±0:30	5:38±0:23	5:19±0:34	5:37±0:43	5:18±0:25	5:29±0:24
	30-34		5:45±0:45	5:31±0:24	5:20±0:20	5:33±0:31	5:33±0:25	5:29±0:27
	35-39		6:20±0:50	6:03±0:42	5:37±0:33	5:56±0:44	5:44±0:26	5:29±0:25
	40-44		6:24±0:46	5:54±0:41	5:56±0:44	6:03±0:51	5:57±0:30	5:50±0:26
	45-49		6:40±0:58	6:16±0:31	6:34±1:02	6:31±0:55	6:19±0:28	6:03±0:29
	50-54		7:17±1:31	6:43±0:31	6:40±0:44	6:56±1:07	6:09±0:26	6:10±0:33
	55-59		7:26±0:48	7:07±0:50	7:04±0:39	7:17±0:45	6:42±0:35	6:31±0:48
	60-64		7:42±1:00	7:31±0:35	7:27±0:41	7:45±0:58	7:21±0:36	7:02±0:40
	65-69		8:42±1:48	8:53±1:17	7:58±0:54	8:13±1:02	7:36±0:51	7:56±0:36
	70-74		8:30±0:57	9:15±1:48	8:53±1:48	9:38±2:00	8:33±0:52	8:18±1:00
	75-79		11:09±3:04	10:29±1:40	9:18±1:24	9:18±1:52	8:37±0:49	10:57±2:30
	80-84		9:47		10:58	13:23±2:29	9:15±1:23	10:33
	85-89							
	90-94							

2000	2002	2004	2006	2008	2010	2012	2014
2:52±0:10	2:56±0:14	2:46±0:06	2:46±0:09	2:46±0:11	2:49±0:09	2:46±0:08	2:47±0:09
2:53±0:11	2:52±0:14	2:48±0:12	2:49±0:10	2:51±0:11	2:48±0:11	2:47±0:09	2:49±0:11
3:04±0:18	3:00±0:21	2:56±0:13	2:54±0:12	2:58±0:12	2:52±0:13	2:53±0:12	2:54±0:13
3:11±0:19	3:03±0:20	3:01±0:12	2:56±0:14	2:59±0:18	3:04±0:14	2:56±0:13	2:57±0:15
3:17±0:24	3:18±0:16	3:04±0:14	3:06±0:16	3:09±0:20	3:02±0:18	3:01±0:13	3:06±0:16
3:37±0:29	3:35±0:24	3:20±0:18	3:19±0:18	3:14±0:19	3:15±0:17	3:16±0:17	3:15±0:19
3:48±0:26	3:40±0:23	3:37±0:19	3:29±0:18	3:34±0:19	3:31±0:18	3:24±0:20	3:23±0:20
4:02±0:38	3:50±0:28	3:41±0:20	3:41±0:25	3:45±0:26	3:31±0:23	3:40±0:21	3:34±0:23
4:30±0:43	4:23±0:24	4:12±0:20	4:01±0:23	4:11±0:59	4:03±0:27	3:59±0:27	3:43±0:22
4:40±0:47	4:28±0:47	4:32±0:23	4:23±0:20	4:25±0:30	4:14±0:28	4:16±0:23	4:15±0:19
5:42±1:00	5:02±0:44	4:57±0:44	4:24±0:32	5:09±0:50	5:02±0:34	5:01±0:36	4:44±0:32
6:05±0:55	5:35±0:17	5:43±0:55	5:45±0:42	6:38±0:10	4:28±0:03		5:04±0:47
5:39	6:18	6:22	5:51		6:02	5:22	
							7:16±0:42
5:59±0:22	5:44±0:09	5:53±0:16	5:52±0:19	5:44±0:13	5:51±0:18	5:45±0:17	5:57±0:23
5:52±0:23	5:51±0:27	5:49±0:23	6:03±0:22	5:55±0:23	5:50±0:24	5:56±0:17	6:01±0:26
6:05±0:27	6:05±0:40	6:09±0:26	6:02±0:25	6:15±0:27	5:52±0:22	5:57±0:22	6:05±0:33
6:46±0:43	6:20±0:34	6:21±0:26	6:05±0:32	6:04±0:31	6:24±0:32	6:08±0:26	6:05±0:30
6:43±0:33	6:59±0:38	6:39±0:34	6:28±0:31	6:38±0:39	6:38±0:42	6:26±0:27	6:23±0:29
7:28±0:57	7:24±0:46	7:06±0:47	6:56±0:32	7:00±0:44	6:53±0:41	6:58±0:43	6:54±0:46
7:56±0:43	7:45±0:46	7:41±0:46	7:28±0:45	7:44±0:48	7:31±0:50	7:06±0:44	7:09±0:43
8:20±0:41	8:30±0:59	8:06±0:42	8:12±0:46	8:01±0:57	7:40±0:56	7:58±0:48	7:44±0:54
9:26±0:59	9:12±1:00	8:54±0:45	8:49±0:55	8:51±0:47	8:56±0:59	8:07±0:42	8:03±0:51
9:56±1:26	9:22±1:18	9:24±0:56	9:05±0:49	10:00±1:09	10:03±1:26	9:23±0:59	9:06±1:01
12:37±2:14	8:52±0:35	11:32±2:57	9:34±1:07	12:06±2:20	11:25±2:20	10:02±2:13	9:57±1:28
15:17±1:03	11:31	12:01±2:01	13:08±2:00	14:14	16:38		10:15±1:11
20:01					13:11		
							15:21±1:37

2000	2002	2004	2006	2008	2010	2012	2014
2:33±0:08	2:31±0:09	2:26±0:07	2:29±0:07	2:29±0:09	2:26±0:08	2:25±0:05	2:25±0:08
2:35±0:10	2:36±0:12	2:31±0:07	2:27±0:09	2:29±0:08	2:29±0:09	2:30±0:06	2:29±0:09
2:37±0:11	2:38±0:13	2:35±0:08	2:30±0:07	2:34±0:13	2:33±0:09	2:32±0:08	2:33±0:08
2:42±0:13	2:44±0:15	2:37±0:10	2:35±0:09	2:37±0:14	2:37±0:10	2:39±0:09	2:37±0:10
2:49±0:14	2:49±0:13	2:42±0:12	2:39±0:12	2:48±0:16	2:39±0:12	2:42±0:11	2:41±0:12
2:58±0:14	3:00±0:21	2:47±0:11	2:41±0:11	2:48±0:15	2:43±0:12	2:46±0:12	2:44±0:12
3:04±0:16	3:10±0:22	2:56±0:11	2:54±0:13	2:56±0:18	2:54±0:12	2:53±0:12	2:53±0:13
3:17±0:18	3:24±0:24	3:05±0:14	3:04±0:17	3:07±0:21	3:04±0:16	3:05±0:21	3:03±0:13
3:34±0:25	3:31±0:28	3:23±0:16	3:23±0:20	3:24±0:23	3:16±0:18	3:15±0:17	3:10±0:19
3:57±0:22	3:54±0:28	3:44±0:17	3:29±0:15	3:38±0:27	3:35±0:23	3:35±0:19	3:37±0:20
4:25±0:53	4:00±0:23	3:53±0:21	3:53±0:20	3:53±0:30	3:40±0:26	3:44±0:25	4:09±0:27
4:36±0:44	4:12	4:27±0:26	4:24±0:51	4:03±0:33	4:39±0:24	4:25±0:32	4:18±0:29
5:18±0:11	6:15	5:44		6:23±0:46	5:12±1:10	5:13±1:10	5:33±0:51
6:49							
5:29±0:21	5:21±0:23	5:20±0:17	5:15±0:17	5:14±0:23	5:22±0:16	5:15±0:17	5:18±0:22
5:27±0:24	5:31±0:28	5:29±0:19	5:20±0:22	5:26±0:22	5:23±0:21	5:23±0:17	5:21±0:25
5:35±0:29	5:28±0:21	5:26±0:23	5:18±0:20	5:30±0:32	5:29±0:25	5:26±0:20	5:28±0:19
5:51±0:31	5:43±0:34	5:40±0:25	5:30±0:22	5:27±0:22	5:34±0:22	5:30±0:20	5:34±0:21
6:02±0:25	6:03±0:27	5:40±0:24	5:34±0:23	5:42±0:34	5:42±0:26	5:39±0:25	5:37±0:27
6:21±0:40	6:20±0:38	6:07±0:31	5:53±0:20	6:02±0:39	5:49±0:29	5:52±0:21	5:54±0:27
6:38±0:35	6:43±0:42	6:36±0:26	6:18±0:27	6:39±0:40	6:19±0:28	6:18±0:25	6:12±0:33
7:15±0:37	7:07±0:51	6:49±0:39	6:46±0:36	6:45±0:39	6:45±0:29	6:42±0:38	6:36±0:34
7:28±0:37	7:31±0:41	7:31±0:40	7:18±0:40	7:34±0:45	7:02±0:28	7:17±0:41	7:09±0:51
8:24±0:38	7:59±0:47	8:13±0:50	7:34±0:30	8:01±0:57	8:12±0:50	7:48±0:44	7:49±0:48
9:19±1:36	9:02±1:29	8:29±1:14	8:51±0:59	8:42±1:09	7:43±0:35	8:37±0:55	9:31±1:33
9:54±1:01		10:34±0:49	9:26±1:52	10:08	9:51±0:44	10:39±1:33	9:23±2:01
11:52	13:49	13:15			8:34		11:47±2:50
13:52							

TABLE IV.—*Results of the mixed-effects regression analyses for performance in age groups.*

		Estimate	Standard error	df	t	P value
25-29 years	Constant term [200 m]	151.62	0.83	1406.77	182.27	<0.0001
	[sex=women]	20.49	1.13	1396.91	17.98	<0.0001
	[distance=400 m]	172.22	1.01	655.37	169.42	<0.0001
	[sex=women] × [distance=400 m]	13.17	1.46	690.41	8.98	<0.0001
30-34 years	Constant term [200 m]	154.74	0.89	1543.88	171.99	<0.0001
	[sex=women]	21.07	1.33	1552.44	15.76	<0.0001
	[distance=400 m]	175.17	0.98	685.70	177.69	<0.0001
	[sex=women] × [distance=400 m]	15.40	1.51	726.49	10.15	<0.0001
35-39 years	Constant term [200 m]	159.68	1.06	1512.63	150.02	<0.0001
	[sex=women]	22.91	1.55	1510.47	14.69	<0.0001
	[distance=400 m]	179.83	1.18	635.15	151.17	<0.0001
	[sex=women] × [distance=400 m]	16.33	1.81	670.09	8.98	<0.0001
40-44 years	Constant term [200 m]	163.22	1.15	1544.27	141.71	<0.0001
	[sex=women]	27.50	1.72	1554.88	15.99	<0.0001
	[distance=400 m]	184.21	1.27	760.23	144.07	<0.0001
	[sex=women] × [distance=400 m]	23.68	1.94	783.89	12.18	<0.0001
45-49 years	Constant term [200 m]	169.46	1.26	1438.36	133.96	<0.0001
	[sex=women]	27.56	1.93	1472.35	14.25	<0.0001
	[distance=400 m]	191.76	1.41	717.71	135.86	<0.0001
	[sex=women] × [distance=400 m]	23.28	2.19	774.60	10.60	<0.0001
50-54 years	Constant term [200 m]	177.49	1.89	1255.19	93.64	<0.0001
	[sex=women]	32.62	2.72	1282.10	11.96	<0.0001
	[distance=400 m]	202.95	2.20	722.60	91.90	<0.0001
	[sex=women] × [distance=400 m]	27.82	3.12	740.35	8.90	<0.0001
55-59 years	Constant term [200 m]	189.38	1.98	994.49	95.35	<0.0001
	[sex=women]	37.33	2.87	1001.97	12.99	<0.0001
	[distance=400 m]	214.33	1.86	540.98	115.21	<0.0001
	[sex=women] × [distance= 400 m]	29.38	2.67	545.29	10.97	<0.0001
60-64 years	Constant term [200 m]	199.34	2.39	798.07	83.14	<0.0001
	[sex=women]	41.36	3.61	791.78	11.43	<0.0001
	[distance=400 m]	226.25	2.18	495.56	103.54	<0.0001
	[sex=women] × [distance=400 m]	31.80	3.17	484.01	10.03	<0.0001
65-69 years	Constant term [200 m]	215.32	2.94	661.64	73.09	<0.0001
	[sex=women]	46.65	4.44	651.09	10.48	<0.0001
	[distance=400 m]	243.60	2.60	390.33	93.50	<0.0001
	[sex=women] × [distance=400 m]	32.80	4.07	401.11	8.05	<0.0001
70-74 years	Constant term [200 m]	230.54	4.33	517.89	53.24	<0.0001
	[sex=women]	56.08	6.70	518.29	8.36	<0.0001
	[distance=400 m]	263.66	4.15	343.46	63.48	<0.0001
	[sex=women] × [distance=400 m]	52.67	6.32	343.39	8.32	<0.0001
75-79 years	Constant term [200 m]	257.43	8.00	281.57	32.17	<0.0001
	[sex=women]	61.64	12.36	285.59	4.98	<0.0001
	[distance=400 m]	297.70	7.66	193.66	38.82	<0.0001
	[sex=women] × [distance=400 m]	77.40	13.32	215.75	5.80	<0.0001
80-84 years	Constant term [200 m]	284.84	12.16	114.82	23.42	<0.0001
	[sex=women]	70.88	19.50	111.29	3.63	<0.0001
	[distance=400 m]	333.10	12.35	71.55	26.95	<0.0001
	[sex=women] × [distance=400 m]	85.67	18.14	64.17	4.72	<0.0001
85-89 years	Constant term [200 m]	337.02	25.13	29.60	13.41	<0.0001
	[sex=women]	72.65	46.06	31.55	1.57	0.125
	[distance=400 m]	385.97	35.87	18.21	10.75	<0.0001
	[sex=women] × [distance=400 m]	290.69	65.41	20.42	4.44	<0.0001
90-94 years	Constant term [200 m]	418.77	28.72	7.33	14.57	<0.0001
	[sex=women]	17.52	35.17	7.33	0.49	0.633
	[distance=400 m]	420.07	32.78	3.79	12.81	<0.0001
	[sex=women] × [distance=400 m]	76.17	40.15	3.79	1.89	0.134

Performance trends

Tables II and III summarize race times for women and men for 200 m and 400 m and Table IV the results of the mixed-effects regression analyses. For age groups 25-29 to 90-94 years, women and men performance improved across years. For age groups 25-29 to 80-84 years, men were faster than women. For age group 85-90 and 90-94 years, however, women were not slower than men. Sex and distance showed a significant interaction in all age groups from 25-29 to 85-89 years, but not for 90-94 years.

Sex difference

Figure 5 presents the trend in sex difference across years. In 200 m, women reduced the sex difference. In 200m, there was a sex×calendar year interaction of trivial magnitude ($P=0.025$, $\eta^2=0.003$) on race time, where a larger improvement in women was noticed. A main effect of sex on race time ($P<0.001$, $\eta^2=0.101$) of medium magnitude was observed, where men were faster than women. Also, a main effect of calendar year on race time ($P<0.001$, $\eta^2=0.064$) of medium magnitude was shown, where race time improved across years. In 400m, there was not any sex×calendar year interaction on race time ($P=0.101$, $\eta^2=0.004$). A main effect of sex on race time ($P<0.001$, $\eta^2=0.101$) of medium magnitude was observed, where men were faster than women ($P<0.001$, $\eta^2=0.081$). A main effect of calendar year on race time ($P<0.001$, $\eta^2=0.037$) of small magnitude was shown, where race time improved across years. In summary, the sex and the calendar year had larger effect on race time in 200 m than in 400 m.

Discussion

The aim of this study was to investigate trends in changes in participation, performance and sex difference in performance in individual medley master swimmers competing in the FINA World Masters Championships in 200m and 400m with the hypothesis that participation would increase and performance would improve across years. The most important findings were: 1) the participation of swimmers older than 35 years in 200 m and of swimmers older than 50 years in 400 m increased; 2) more men competed in 200 m and 400 m; 3) women and men improved performance across years in all age groups from 25-29 to 90-94 years; 4) men were faster than women from 25-29 to 80-84 years, but not from 85-89 to 90-94 years; and 5) women reduced the gap to men only in age groups from 40-44 to 45-49 years.

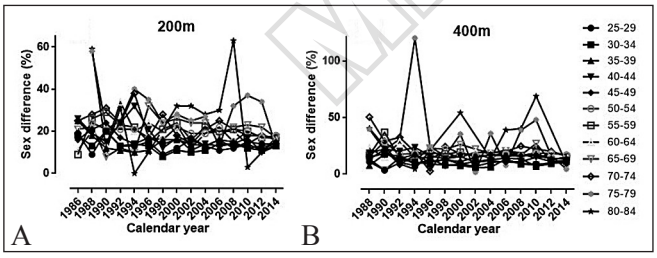

Figure 5.—A, B) Sex differences in performance by age group and calendar years.

Participation increased in women and men in the older age groups

A first finding was that participation in individual medley master swimmers increased in older age groups (>35 years in 200 m and >50 years in 400 m). The youngest age group in the FINA World Masters Championships is 25-29 years.[1] It is very likely that swimmers in the younger age groups (*i.e.* younger than 30 years) preferably compete in races held at world class level such as the World Championships and the Olympic Games.[4, 19, 20] The fastest race times in elite swimmers are achieved at the age of ~21-25 years.[19]

The increase of participation in swimmers in older age groups might be explained by the increase in life expectancy in recent decades.[21-24] Considering the World Population Ageing Report from 2013,[25] the global share of older people (aged 60 years or over) increased from 9.2% in 1990 to 11.7% in 2013 and will continue to grow as a proportion of the world population, reaching 21.1% by 2050. The older population is itself ageing. Globally, the share of older persons aged 80 years or over within the older population was 14% in 2013 and is projected to reach 19% in 2050. The older population is predominantly women. Because women tend to live longer than men, older women outnumber older men almost everywhere. In 2013, globally, there were 85 men per 100 women in the age group 60 years or over and 61 men per 100 women in the age group 80 years or over. Due to improvements in health, 80-year-old will have levels of both physical and mental capacities similar to that of many 20-year-olds.[26]

More men competed in 200 m and 400 m

The finding of more men than women competing in 200m and 400m was in agreement with previous swimming events. For instance, when we consider long-distance swimming events such as the English Channel Swim,[27] the Catalina Channel Swim [28] or the Manhattan Island Marathon Swim,[29] more men than women were competing. Also for shorter long-distance races such as 10km swimming, men more than women were competing.[30]

Women and men improved performance in all distances

With regards to performance trends, women and men improved performance in all age groups and for all distances. This confirms previous findings for age group marathon runners [16] and age group swimmers.[13, 31] However, this is the first study to show that octogenarians and nonagenarians improved performance in individual medley swimming. In the study of Akkari *et al.*[13] investigating age groups swimmers and Lepers and Cattagni [16] investigating age group marathoners, the oldest swimmers considered were competing in age group 75-79 years. A very recent study investigating marathoners older than 75 years competing between 2004 and 2011 showed, however, that participation for women and men runners remained unchanged and the fastest women and men became slower across years.[14]

A potential explanation that these elderly swimmers improved performance could be their training. It has been shown that training distance in older master swimmer aged 52-82 years may be an important factor for maintaining muscle mass and function in the aging process.[32] A study investigating French master swimmers showed positive health outcomes regarding different aspects such as weight management, respiratory function, and vitality due to their race preparation where positive health outcomes were higher for women master swimmers.[33]

Women were not slower compared to men in age groups 85-89 to 90-94 years

Considering the variation of sex differences by age group, men were faster than women in age groups 25-29 to 80-84 years, but not in age groups 85-89 to 90-94 years. The most likely explanation might be the very low number of women and men competitors older than 85 years. Another explanation might be anthropometric differences between elderly women and elderly men since there seemed to be differences between the sexes regarding an age-related loss in skeletal muscle mass. Men older than 70 years lose significantly more fat-free mass than women of the same age [34] and in 68-78 years old women and men, the rate of loss in leg muscle was significantly higher in men than in women.[35] With higher ages, sarcopenia occurs more frequently in men then in women. In women and men older than 80 years, the prevalence of sarcopenia was ~31% in women and ~53% in men.[36]

Decrease of sex difference in middle age groups

Another important finding was that women were able to reduce the gap to men only in the age groups 40-44 to 45-49 years. This trend should not be attributed to any age-related physiological mechanism. The sex differences were decreased mostly in those age groups, which showed the largest differences in the first championships. Thus, the different trend of the age groups 40-44 and 45-49 years from the others might be interpreted by their baseline values.

Limitations and strengths of the study

A limitation of this study was that the individual medley, despite being a combination of all swimming strokes, has certain physiological differences than the other strokes separately.[37] Thus, caution is needed to generalize the finding of this study to the other strokes. On the other side, the present study is one of the few ever carried out on individual medley, and its findings might enhance the understanding of both sports scientists and swimming practitioners about major performance characteristics of this event.

Conclusions

In summary, in age group individual medley swimmers competing in age groups 25-29 to 90-94 years in the FINA World Masters Championships between 1986 and 2014, the participation increased in 200 m in swimmers older than 35 years, whereas in 400 m in swimmers older than 50 years; more men competed in 200m and 400m; women and men improved performance in all in age groups from 25-29 to 90-94 years; men were faster than women from 25-29 to 80-84 years, but not from 85-89 to 90-94 years; and women were only able in 40-44

to 45-49 years to reduce the gap to men. These data suggest that especially elder (geriatric) master swimmers will continue to increase their participation and improve their performance in individual medley swimming.

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